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CARGO GENERATION FORECASTING MODELS, (U)

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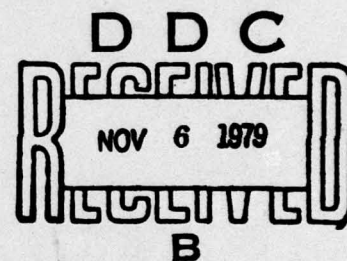
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FRANK J. SEILER RESEARCH LABORATORY

SRL-TR-79-0010

OCTOBER 1979

CARGO GENERATION FORECASTING MODELS



LT COL JOHN S. BRUSH

PROJECT 2304

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UNITED STATES AIR FORCE

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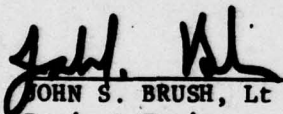
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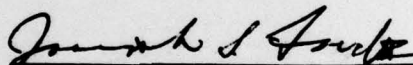
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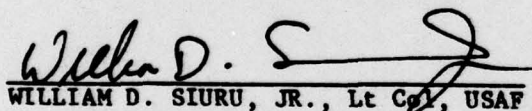
This report has been reviewed by the Chief Scientist and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

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## I. Introduction

This report describes the development of a time series forecasting model for daily cargo generated for two military airlift command (MAC) routes. The models represent application of a two-stage identification and modeling approach wherein ARIMA models of the input variables were first developed to identify basic periodicity or seasonality. With some insight into the process relationship of the input variable, cargo arrivals, and the output variable, shipment ready cargo, a general model admitting a wide class of functional relationships was postulated and the best fitting models within this class identified. Surprisingly the 4 and 7 day forecasting models for both routes exhibited the same structure.

## II. Description of Process

At a typical MAC base, cargo for airshipment arrives daily by various transportation modes. Before it can be made ready for airshipment, it must first be processed. Processing requires both administration procedures and usually physical repackaging of arriving cargo.

Considering cargo arrival per day as the input into the system, it can be assumed that preparing it for shipment represents a smoothing process. Specifically, because of physical and personnel limitations, there is an upper limit on the amount of cargo that can be processed per day. It is presumed that manning and physical storage facilities are set at levels that comfortably deal with average processing demand levels, and that cargo that cannot be processed in any one day is stored and processed in following days. Thus, peaks and troughs in daily cargo arrival are smoothed and filled in by the airshipment preparation process.

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### III. Modeling Approach

The object is to construct a model of the daily cargo generation process. The model is to be used for forecasting up to 7 days in advance. The two random variables of interest are:

$AR_t$  Arriving cargo in tons per day

$MR_t$  Movement ready cargo on tons per day

A general functional specification consistent with the approach taken herein is to suppose that movement ready cargo at some number of days ( $k$ ) in the future is related to both movement ready and arriving cargo in the current and all past days. Or

$$MR_{t+k} = f(MR_t^*, AR_t^*)$$

Here and henceforth the starred superscript specifies a vector of all past values of the noted variable beginning at period  $t$ . In practice, first differences of daily arrivals are used so that the model is:

$$MR_{t+k} - MR_t = f \left( (MR_t - MR_{t-1})^*, (AR_t - AR_{t-1})^* \right) \quad (1)$$

Previous work on the cargo arrival series has revealed an ARIMA structure of (1,1,7) in the conventional notation. This indicates a strong weekly seasonality in the presence of a shorter term negative autoregressive structure. Simply, it appears that short term (two day) changes are, other things equal, corrected in the next few days while Sundays and Mondays are slow days for cargo arrival. The conventional Box-Jenkins [1] approach to this problem is to first model the movement ready process exploiting its stochastic structure and then to use the

prewhitened residual series to identify the weighting structure of a combined model. However, in this case, there is reason to suspect a functional relationship suggesting that  $MR_t$  is in some sense the backward time integral of  $AR_{t-1}^*$ . Accordingly, this knowledge is used to directly test model forms.

The approach taken was to admit a general model structure, then fit using a generalized inverse algorithm with an adaptive serial correlation estimator [2]. A nonlinear two term quadratic approximation was at first attempted with the finding that the second order and product terms added little to fit. This can be viewed as a test for at least local nonlinearity. Consequently, models presented in the next section are specializations of the following form:

$$MR_{t+k} - MR_t = w^T(MR_t - MR_{t-1})^* + g^T(AR_t - AR_{t-1})^* + h + \theta^T(\epsilon_t)^* \quad (2)$$

Polynomial distributed lag structures to third order were used in tests of variable dimension lag vectors  $w$  and  $g$ . It was found that serial correlation was not present (to seven lag periods) so the final models are rather simple autoregressive forms.

#### IV. Results

Four different models were constructed, two for the Dover-Frankfurt channel and two for the Dover-Ramstein channel using daily data for July through October 1978. For each channel a four and seven day horizon model was developed. The resulting models are described by the following equation:



$$MR_{t+k} - MR_t = a + b(AR_t - AR_{t-4}) + \sum_{j=0}^{j=5} w_j (MR_{t-j} - MR_{t-j-1}) \quad (3)$$

Coefficients and summary fit statistics (T-statistics in parentheses) are:

Model	a	b	w <sub>0</sub>	w <sub>1</sub>	w <sub>2</sub>	w <sub>3</sub>	w <sub>4</sub>	w <sub>5</sub>	R <sup>2</sup>	d.w.	S.E.
DOV-FRT 7-day k = 7	-.045	.195 (2.4)	-.768 (-5.8)	-.733 (-5.1)	-.661 (-3.7)	-.552 (-2.3)	-.405 (-1.3)	-.221 (-.5)	.304	2.09	27.2
DOV-FRT 4-day k = 4	.363	N/A	-1.108 (-11.2)	-.765 (-6.5)	-.485 (-2.9)	-.268 (-1.1)	-.115 (-.4)	-.025 (-.1)	.601	1.97	30.4
DOV-RMS 7-day k = 7	.449	.150 (2.1)	-.801 (-6.1)	-.730 (-5.0)	-.635 (-3.4)	-.514 (-2.1)	-.368 (-1.1)	-.197 (-.5)	.331	2.14	17.6
DOV-RMS 4-day k = 4	.501	N/A	-1.128 (-11.7)	-.811 (-7.0)	-.545 (-3.3)	-.332 (-1.4)	-.169 (-.5)	-.059 (-.1)	.611	2.09	18.7

It is notable that both channels yield very similar models. The stochastic structure can be stated simply as noting that an increase in movement ready cargo over a delay weighted five day horizon is generally followed by a reduction in movement ready cargo over the next four and over the next seven days. Note the negative weights of w<sub>0</sub> through w<sub>5</sub>. These weights are more significant for recent changes. Arrivals enter into the stochastic structure in a more complex way. For seven day horizons in both channels, increases in arrival cargo over the past four days lead to increases in movement ready cargo. These terms are quite significant. For the four day horizon, the past arrival term is absent. Attempts to improve the four day movement ready models by utilizing past values of arrivals were not successful.

It was originally postulated that movement ready cargo would be in some sense a moving average or past time integral of past values of arrivals. In fact, past changes in arrivals are not as helpful as past changes in movement ready in forecasting changes in movement ready. In addition, no forecasting improvement was obtained by treating the difference between arrivals and movement ready as a proxy for backlog. Alternative lag structures and lag complexities were investigated, but the reported results seem to fit the best. The reported weights are for a quadratic, constrained to zero seven days in the past. Only two terms are needed to specify the lag function over the six weights. Note that the shape of the lag structure is closer to a linear decay or moving average than to an exponential.

Note the very similar structure of both models. Because both channels have similar stochastic structure in arrivals, it is difficult to tell whether similar movement ready models are a result of input similarities or processing system similarities.

## V. Conclusions

Several findings resulted from this study. First and perhaps most interesting is the fact that movement ready cargo like arrival cargo enjoys a strong weekly cyclical pattern. Counter intuitively this weekly pattern is not a direct shift of the arrival pattern, but rather seems to have its own unique stochastic structure. A more satisfying result is the finding that on a seven day horizon, past arrivals do influence movement ready in a positive manner indicating some backlog effect. This implies that an increase in arrivals does (other things equal) imply a

future increase in movement ready, but on a 7-day, not a 4-day horizon. It appears from these results that roughly one-third of fluctuations in movement ready can be explained 7 days in advance, but that sixty percent of fluctuations in movement ready can be explained 4 days in advance. Also interesting is the finding that the models developed for two different routes have very similar structures. The fact that both channels are served by the same origin, Dover AFB, may or may not explain the similarity in model structure. Future efforts might investigate this question.



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